Evaluation of the cloud fields in the UK Met Office HadGEM3-UKCA model using the CCCM satellite data product to advance our understanding of the influence of clouds on tropospheric composition and chemistry

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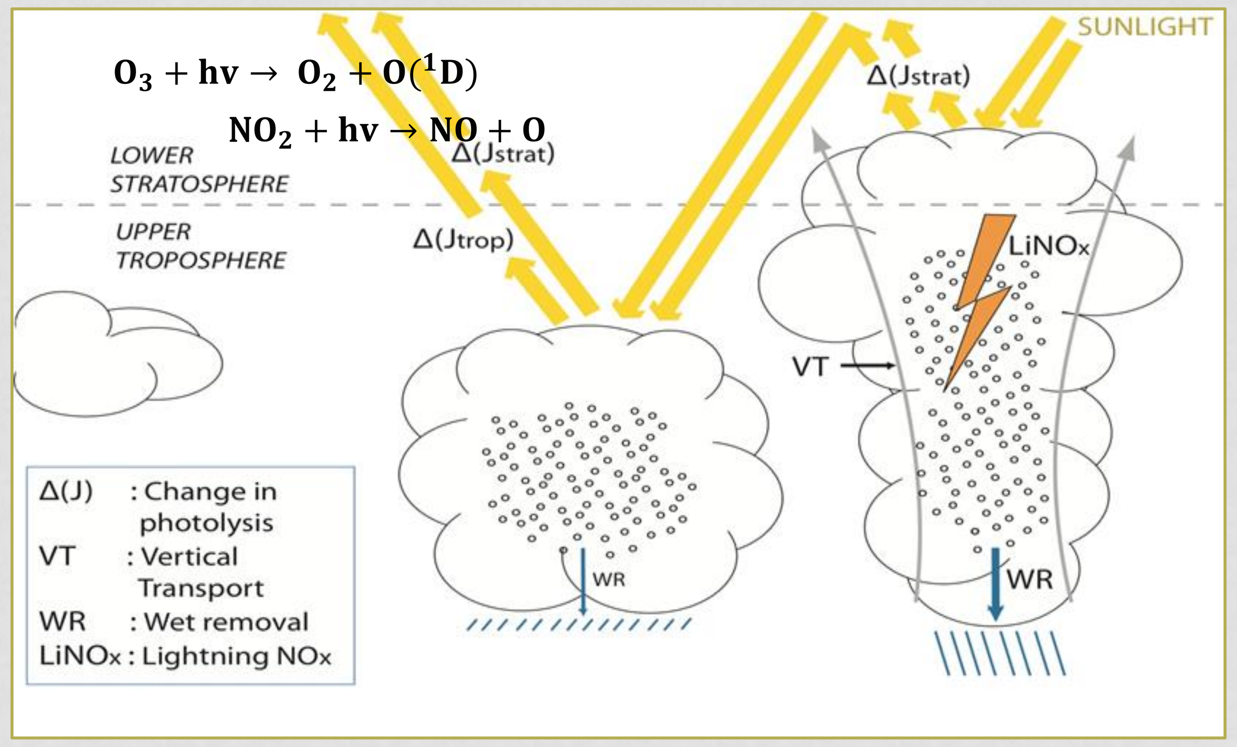
INTRODUCTION

As well as absorbing and scattering radiation, clouds are involved in a variety of processes that influence constituent composition in the UTLS. These include:

- the modification of photolysis rates of gaseous molecules through the backscattering of radiation (Δ(J));[1,2]
- convective transport, upwelling (VT) and wet removal processes (WR); and [2,3,4,5,6]
- NO_x emissions from lightning ($LiNO_x$).[7]



AIM

To determine the role of clouds in driving inter-annual and inter-seasonal variability of trace gases in the troposphere and lower stratosphere with a particular focus on the importance of cloud modification of photolysis.

To evaluate the cloud fields and their vertical distribution in the HadGEM3 model utilizing CCCM, a unique 3-D cloud data product merged from multiple A-Train satellites (CERES, CloudSat, CALIPSO, and MODIS) developed at the NASA Langley Research Center.

EVIDENCE OF CLOUD MODIFICATION OF PHOTOLYSIS GLOBALLY

i)

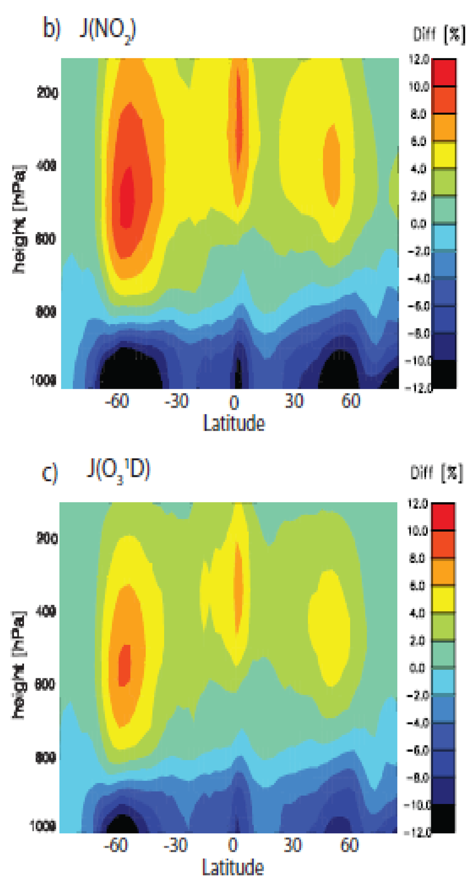
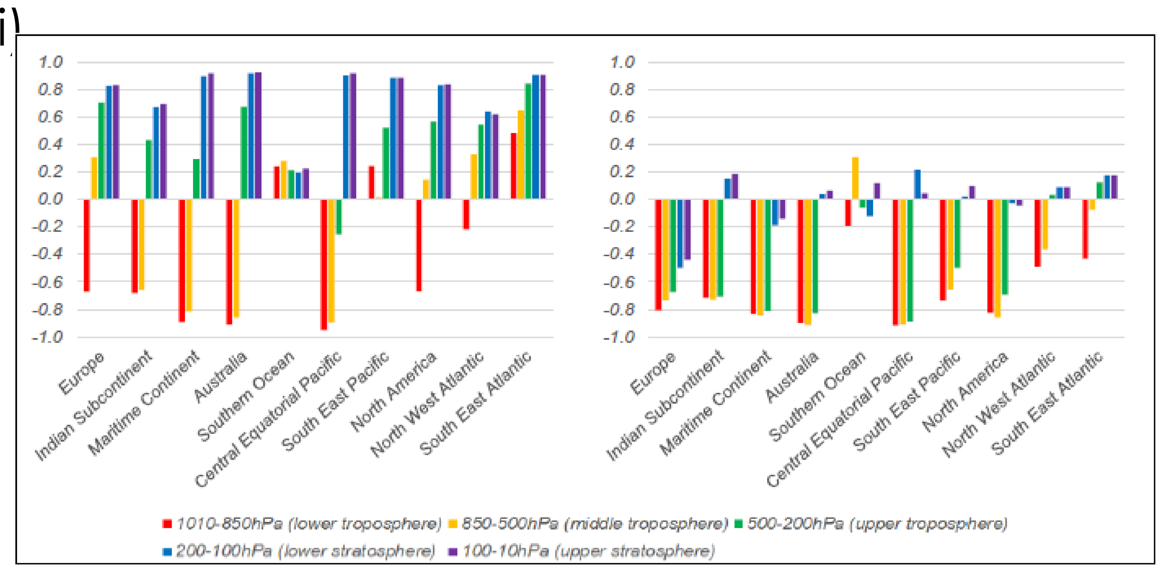


Figure i) shows zonal mean percentage differences in annual mean $J(NO_2)$ and $J(O^1D)$ between model runs 1) incorporating ECMWF cloud data and 2) removing clouds.[1] There are net increases in $J(O^1D)$ and $J(NO_2)$ rates across the upper troposphere and net decreases in the lower troposphere.[1]

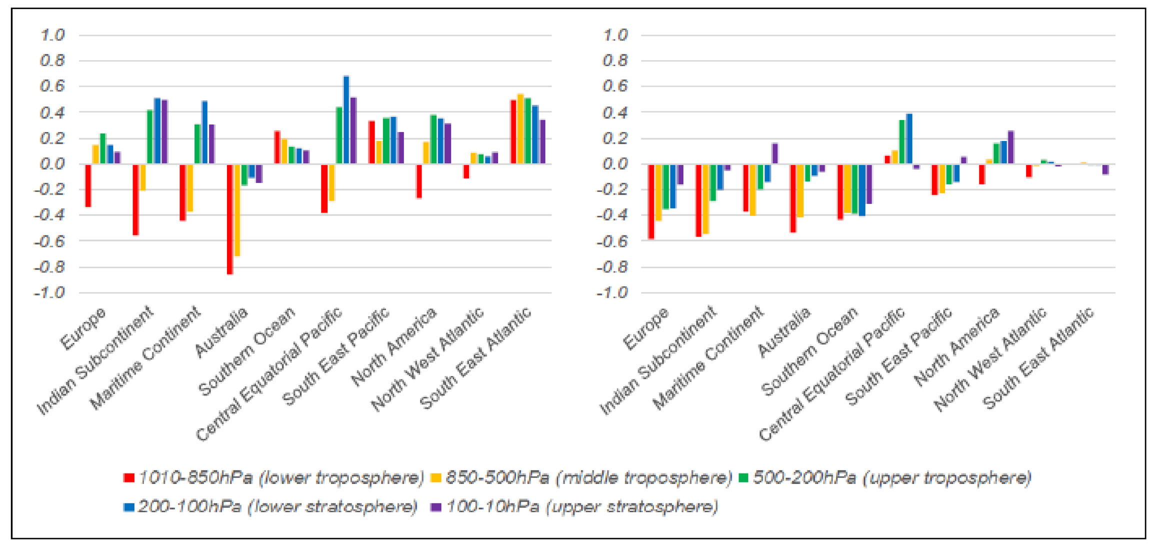
Figure ii) shows regionally that clouds are strongly correlated with $J(NO_2)$ and $J(O^1D)$ over several regions following a similar pattern to correlations globally although these correlations are stronger in the MESSy model and overall with $J(NO_2)$.

EVIDENCE OF CLOUD MODIFICATION OF PHOTOLYSIS REGIONALLY: 2 CCMI MODEL HINDCAST SIMULATIONS 1960 - 2009

ii)



Correlation Coefficients of 2D cloud fraction and $J(O^1D)$ for 5 vertical pressure levels as calculated from MESSy: EMAC-L47MA (left) and ETH-PMOD:SOCOL3 (right)



Correlation Coefficients of 2D cloud fraction and $J(NO_2)$ for 5 vertical pressure levels as calculated from MESSy: EMAC-L47MA (left) and ETH-PMOD:SOCOL3 (right)

REFERENCES

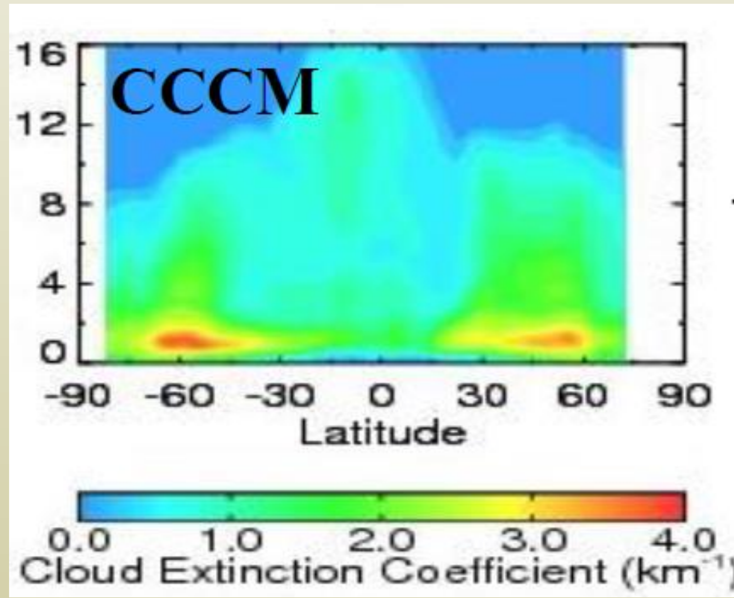
(1) Voulgarakis, A., et al., Atmos. Chem. Phys., 9, 8235–8246 (2009) **(2)** Liu, H., et al., J. Geophys. Res., 114, D10305, (2009) **(3)** Tselioudis, G., et al., Geophys. Res. Lett., 37, L14806 (2010) **(4)** Solomon, S., et al., Geophys. Res. Lett., 32, L23813 (2005) **(5)** Scheuer, E., et al., J. Geophys. Res., 115, D00J03 (2010) **(6)** Randel, W.J. et al., Science, 328 (5978), 611–613 (2010) **(7)** Price, C., et al., J. Geophys. Res., 100, 5929–5941 (1997) **(8)** Crawford, J., et al., J. Geophys. Res., 104, 5725–5734 (1999) **(9)** Brieglieb, B.P., J. Geophys. Res., 97, 7603 – 7612 (1992) **(10)** Liu, H. et al., AGU Fall Meeting (2014)

HOW ACCURATE ARE MODEL CLOUD FIELDS? AN EVALUATION OF HadGEM3

Simulation of clouds varies significantly from model to model which makes the analysis of clouds effects difficult [1,8,9]. We are using the CCCM cloud data product to evaluate the cloud fields and vertical distribution in the HadGEM3 Met Office Model and to quantify the influence of the model's bias on its simulation of key tropospheric and lower stratospheric key trace gases.

First stage evaluation shows the initial comparison of cloud extinction coefficients(CECs) as observed by CCCM and simulated by HadGEM3 for January 2008.

iii)



iv)

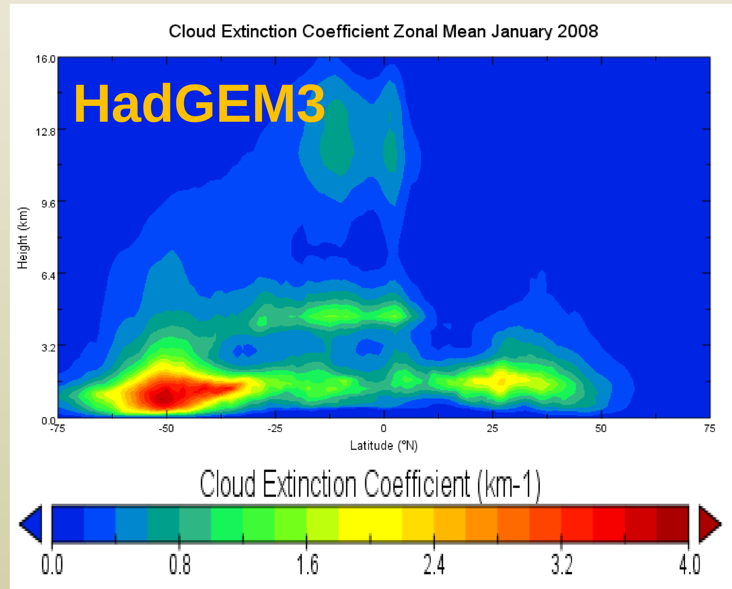


Figure iii)[10] shows CCCM's CECs are higher in the mid-latitudes and lower in the tropics.[10] Figure iv) shows HadGEM3 captures CCCM's CEC distribution reasonably well.
In the next phase, we will calculate monthly mean effective cloud optical depth for every month in 2008 for CCCM and the model using the approximate random overlap approximation[2,9], used in the model's photolysis calculation as follows:

$$\tau_C' = \tau_C * f^{3/2}$$

where :
τ_C' is the grid-box ECOD [2,9];
τ_C is the cloud optical depth in the cloudy portion of the grid [2,9]; and
f is the cloud fraction in each layer[2,9].
We will then:
•obtain monthly mean scaling factors from the ratio of CCCM's ECODs to the model's;
•apply these scaling factors to constrain the model's cloud field right before its photolysis calculation at each time step and then re-run the model; and
•examine the impacts on (and changes to) chemistry from the re-run.

CONCLUSION AND FUTURE WORK

- Model analysis to date show that there is some association between clouds and modification of photolysis, a key driver of chemistry in the atmosphere.
- Initial evaluation of HadGEM3 with CCCM shows that the model captures clouds reasonably well.
- Using the scaled HadGEM3 model we will perform sensitivity experiments to determine the key drivers of constituent variability and to further our understanding of the regional importance and influence of clouds on key trace gases.